So what "EXACTLY" is science?

Many philosophers have tried to define modern science or to describe the essence of modern science in a few words. None of them is convincing because words alone are not sufficient to do so. It is easy to give discourses on the need for a scientific outlook but they serve no purpose. Understanding the strengths and the limitations of various aspects of science is necessary for the development of real scientific outlook.

Among all animals, chimpanzees are genetically closest to humans. Scientists observed that chimpanzees perform primitive scientific actions. For example, they use small stones and sticks as tools. They use leaves as bandages over their wounds. Human language is obviously far superior to any other animal language. This was the key for the rapid entry of humans into all the continents described earlier. Human cultural progress began with the scientific capabilities of fire and stone tools. Scientific progress, the key to this cultural development was shared, initially orally and later on through written records.

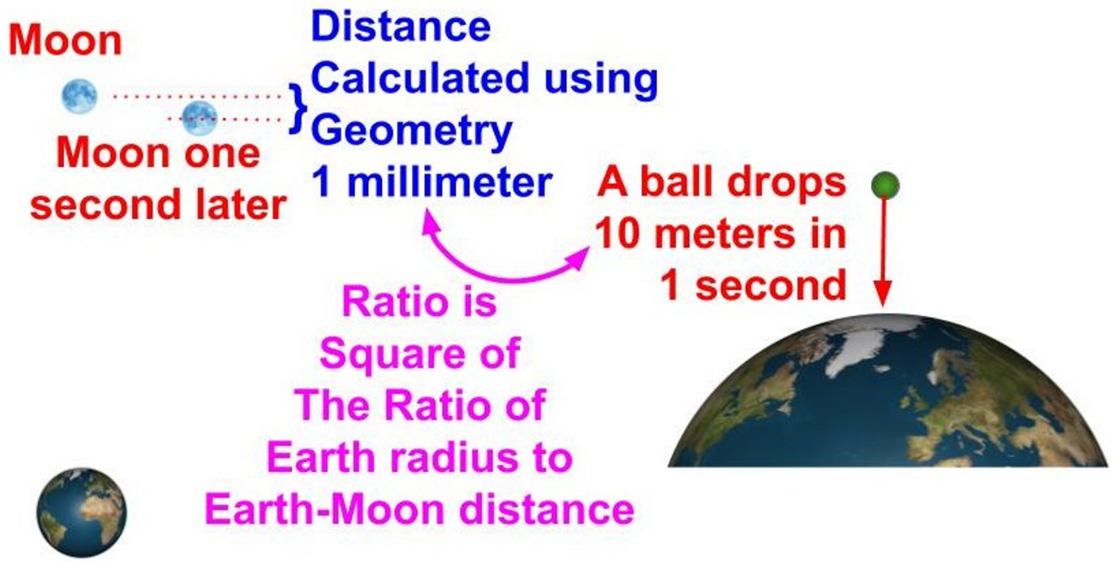
This exclusive reliance on words and numbers was fundamentally changed by Euclid’s book "Elements". Mathematics which earlier was only a process of counting with numbers became proof of theorems. For example, Pythagoras theorem was certainly described by many earlier scholars. The theorem says that the square of the hypotenuse is equal to the sum of the squares of the other two sides of a right angled triangle, If the sides of the right angled triangle are 3,4,5 obviously 3x3+4X4= 5x5. There are many ways in which people could have guessed that this is true for all right angled triangles. Other examples like 5,12,13 are easily available. It is possible to cut paper and show that the theorem holds but there may be gaps which are not easily visible. Most masons and builders may have known that the theorem is always true. But how to prove that there will never be a right angled triangle which will not obey the theorem?

Euclid accepted certain logical statements which no one can deny as obvious truths. For example, "the whole is larger than the part". Then he assumed certain properties of an ideal line and point. From these he showed that there can never be a right angled triangle that does not obey Pythagoras theorem. Similarly we can show that the square root of the number 2 cannot be written as a fraction. There are countless numbers and triangles. The fundamental new idea brought in by Euclid was that we can come to a conclusion without having to actually check all the numbers one by one or measure all triangles. Mathematics was changed from counting to proving theorems.

One example is sufficient to prove that a theorem is wrong. But any number of examples do not suffice to prove that a theorem is correct. Even if one example contradicts a true theorem, there will be innumerable problems. For example everyone knows that 2+3=3+2. That "the order in which you add will not make any difference to the sum" is a theorem of mathematics. There cannot ever be any exception to it. But assume that x and y are two numbers for which x+y<>y+x where <> is the symbol for not being equal. This does not stop here. You will get many other examples. 1+x+y<>x+y+1 also has to be true. This example explains the strength of mathematical theorems.

Earlier, while discussing fundamental physics, we have repeatedly said that an isolated example cannot be the basis for rejecting fundamental physics. The above description of mathematical theorems helps one to appreciate that claim.

Using geometry, Newton found that the moon, in the elliptical orbit, would have moved 1 mm from the straight line, in 1 second. In view of Newton’s first law this change has to be due to a force. On the earth, a body falls a distance of 10 m. in one second. A force is



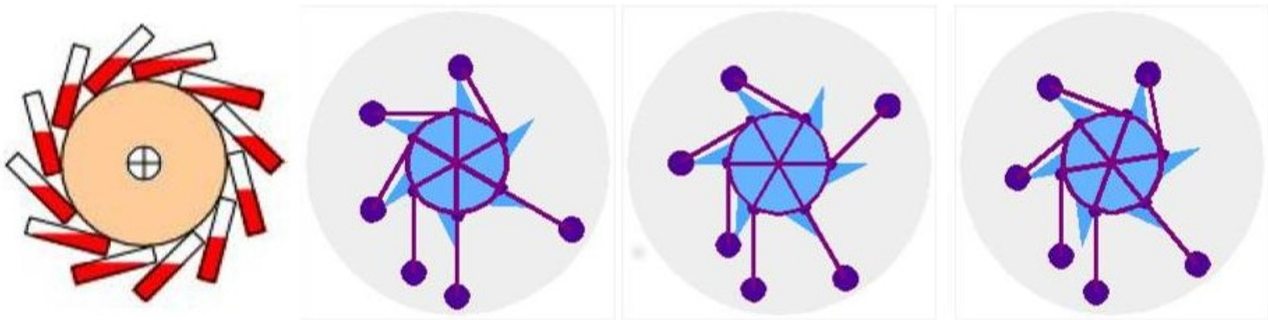
required for this too. Comparing the radius of the earth with the distance between the earth and moon, Newton realized that both movements are caused by the same force. The force varies inversely as the square of the distance. It becomes one fourth the value when the distance is doubled. This was the first time a mathematical relation appeared in physics. Incidentally, Newton did not measure in meters, the familiar units of today. His numbers had to be converted to the newer units.

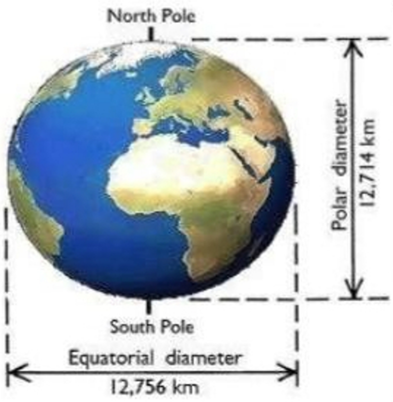
Energy can only be converted from one variety to another. The total will not change. When a wood is burnt, some energy is used for heating water. Some portion is carried away by the steam. Some more is radiated into the surroundings which get heated. It is possible to

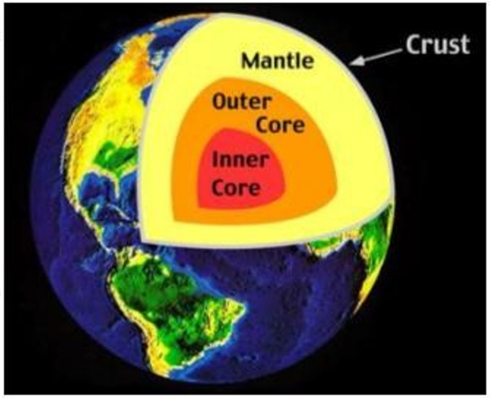
show experimentally that the total energy is constant. As mentioned earlier, more than the experiments, conservation of energy being a part of the mathematical theory of physics is more important. Overruling this strength and claiming the design of machines that can generate infinite energy is unscientific.

Many very famous ancient scholars, from Archimedes to Aryabhatta proposed designs of wheels that move eternally. {Picture below} Usually water falling from the upper cup to the lower is expected to move the wheel. Alternatively the design uses swinging weights. Inspired by these ideas, many modern designs are proposed. Scientists think it a waste of time to check each of them and explain why the idea will not work. Accepting the strength of the mathematical foundation is the first step in developing a scientific world-view.

The second step is to properly understand the meaning of scientific terms. Fed up by the verbal circus of philosophers trying to define every word more and more precisely, by using other words, the famous scientist Richard Ferryman said, "An electron is not a thing. It is the way scientists think". The purpose of scientific terms is not to understand nature. It is to

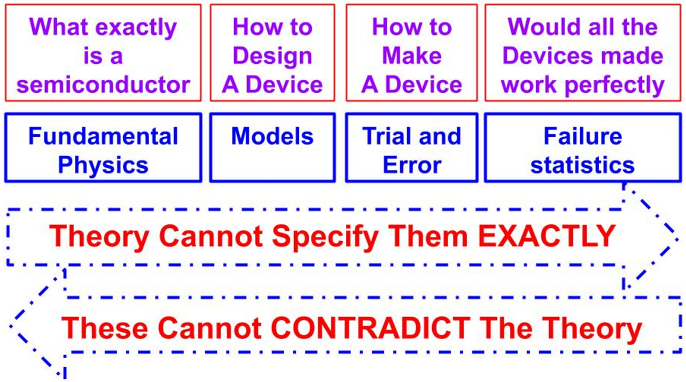






fix the concepts in mathematical relationships and explain experimental results. We make every student in the elementary school recite that the earth is round. {Picture above} But to determine the orbit of the earth around the sun, the earth is a point at which all the mass is concentrated. While designing roads or buildings the earth is flat. When the flight paths of airplanes are decided, the earth is a sphere. To determine the tides, it is a deformed sphere whose diameter along the axis is smaller. For studying earthquakes, the earth is a layered sphere with a heavy core.

The best example to confirm that scientific terms are meant to be used only for explaining experimental results is the fundamental physics theory, quantum mechanics. We can not ever know whether an electron is a particle or wave. This is completely beyond human imagination. But the properties of an electron calculated using quantum mechanics agree with the experiments to the tenth decimal place. This is like calculating the diameter of a



sphere the size of earth and showing that it agrees with experiments to an error less than the thickness of a human hair.

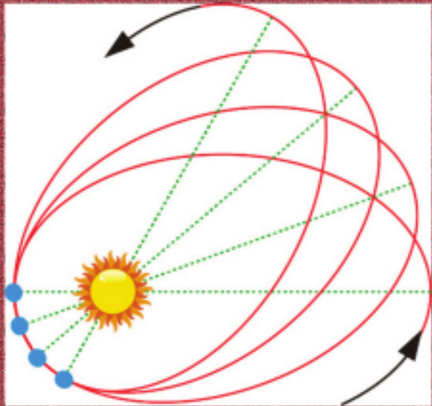
The next most important step for the development of a scientific world-view is to understand how useful in practice a given scientific result actually is. The idea was discussed in the last two chapters. Here, we will try to emphasise this further by describing briefly how the electronic computer "chips" are designed and made.

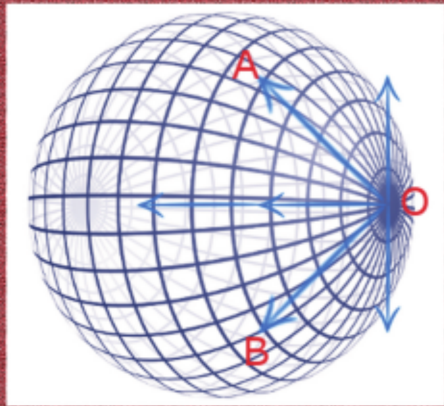
A metal allows electricity to pass through it and is called a conductor. A material like porcelain that does not allow electricity to pass is called an insulator. A semiconductor is a material that is neither a conductor or an insulator. Among elements the most important semiconductor is silicon. Understanding the physics of a semiconductor is impossible without understanding quantum mechanics. Semiconductor switches open or close during the working of any electronic device. In a cell phone for example, there are millions of semiconductor switches, each one controlling others. Even one single switch cannot be completely described using the mathematics of quantum mechanics. The mathematical calculations are beyond our capabilities. So the equations are simplified. {Picture above left} When a chip with millions of switches is to be designed, these simple equations are combined to make a computer model of the chip. The design is approved after testing the model on a computer. So a new computer is designed on an old computer. These models

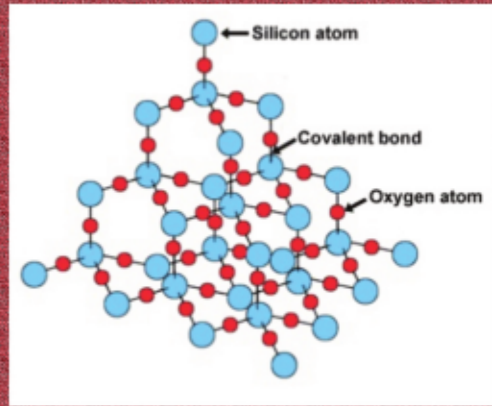
of computer chips are much smaller and simpler than the model of the environment. It is clear however, that our confidence in the simplified equations used in design is a bit less than in the fundamental equations of quantum mechanics.

Next, the design had to be made using a piece of silicon. For this hundreds of physical and chemical processes are used. The temperature, chemicals, etc used in each process are decided by the results of earlier experiments. The results are all mathematical relations. Scientists identify these relations after a lot of simplification of quantum mechanics. Our confidence in these is much less than even that in the model. That piece of silicon sealed in plastic is what we see in our cellphones and computers. We need to confirm that these "chips" will function as designed when the outside temperature, humidity etc are changing. This is done by comparing groups of chips. This statistical method is even more remote from quantum mechanics. In the first fifteen chapters we saw the application of the fundamental laws of physics and comparison of identical groups in different areas of science. We see both in a single area, the fabrication of computer chips. In both cases we notice the strength of the underlying mathematical physics.

But as we move from science to social sciences this backbone disappears and the results are inevitably disputed. To develop a true scientific disposition, it is necessary to avoid emotional commitment to an idealized view of science and learn to evaluate the strength and limitations of individual scientific results. That, rather than blind obedience to the claims of scientists is the truly scientific world view







This book begins with a very simple everyday observation, the movement of the sun in the sky. As the observations are repeated from different locations, at different times of the day and year and with more and more accuracy, a very complex picture emerges. Unexpectedly, all the complexity can be explained using very simple ideas. This is the essence of science. Many areas are covered in this small book, from planetary movement and chemistry to biology and climate change. It has been specifically written for young children. It is not however a collection of facts. Many areas of science can be descriptively understood using a few very elementary ideas of fundamental physics. The aim here is to make the readers understand the interrelationships between the various areas and the strength of fundamental physics with the minimum of scientific terms and no mathematics at all. But as one moves from the movement of planets to living beings and climate, only an approximate explanation is possible. The book explains "how well" we understand, which is very important as the description of some popular unscientific ideas made from time to time shows.